PARAMETRIC OPTIMIZATION OF TURNING OPERATION ON STAINLESS STEEL USING A CARBIDE TOOL

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Mechanical Engineering

By
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National Institute of Technology
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Under the Guidance of
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CERTIFICATE

This is to certify that this thesis entitled, "**PARAMETRIC OPTIMIZATION OF TURNING OPERATION ON STAINLESS STEEL USING A CARBIDE TOOL"** submitted by Mr. **SARBESWAR ROUT** in partial fulfillments for the requirements for the award of Bachelor of Technology Degree in Mechanical Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Date: Prof K. P. Maity

Professor
Department of Mechanical Engineering,
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Rourkela- 769 008

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Dt.

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ABSTRACT:

Microturning is the turning process which involves machining of work pieces at a dimension of 1 to 999 micrometers. As stainless steel is one of the most important and widely used materials in these days; so it is being chosen as the work piece material. The machining parameters are chosen to be cutting speed, feed and depth of cut. The main aim of the experiment is to minimize cutting forces (feed force, the thrust force and cutting force). The aim of the experiment is to minimize the forces, to reduce the chip thickness, to reduce the surface roughness and to reduce the tool wear. The experiment was carried out by lathe, and the forces were measured by a dynamometer. The mode of machining is dry machining. The taguchi method and gray relational analysis are used to obtain the optimum parameters for better machining. Minitab is statistical software which is used to do the analysis part.

1. INTRODUCTION:

Now a day the main motive of the industries is to reduce cost and maximize their profit through improving their technology. In production engineering there is a lot of scope for improvement. A lot of efforts are being made to improve the productivity and machinability of the machines to satisfy the daily increasing needs. Sometime it happens that if we increase the surface finish or decrease the forces then the cost of machining increases in very large amount. So we have to optimize the things in such a way that it should fulfill our both the needs i.e. the cost and quality of product should be optimized.

The term micromachining refers to the machining where process occurs at dimensions of 1 to 999 micrometers. Microturning is one of these processes. Microturning is a conventional machining. But in this case the size of the product and the work piece are much similar. It becomes more and more difficult to machine as the size of the work piece decreases. So manual machining is quite impossible in case of micro machining. So in this case computerized control machines are used.

Advantages of micro tooling machines

1. Micromachining uses less amount of energy than conventional macro machining. They help in saving energy leading towards save of money. During traditional machining a lot of energy consumption occurs which is unnecessary. The consumption of energy is in the order of 100 W. so micromachining is more efficient.

2. In case of large conventional machining the temperature of the machine gradually increases; which is not good for machining. But in case of micromachining the temperature of the machine can be made constant.in conventional machines the need for vibration control system is required. The design of machine bed and vibration isolation system is required. But in case of micromachining such things and arrangements are not required. The natural frequency of micro machine is much higher than the vibration caused by surrounding.

3. Micromachining is easy to install and can be located anywhere in shop floor.it does not require and building or special room for installation. So factory lay out can be easily changed according to the requirement.

2. MINIMUM CHIP THICKNESS:

In microturning, there is a certain minimum thickness chip that greatly affects variables such as cutting force, tool wear, surface integrity and this affects the performance of the manufacturing process. The concept of minimum chip thickness arises because of the edge radius. In microturning, the instrument can be reduced to a large extent, but the sharpness of the tool cannot be reduced that much. So, if the uncut chip thickness is less than the minimum thickness chip, no chip is generated. There are two mechanisms by which the minimum effect of the chip thickness affects the process microturning. They are chip removal and plowing or rubbing. With the increase in the flow of plowing or rubbing, cutting force increases, occurs the formation of burrs and roughness of the surface increases. Thus the analysis of the effect minimum chip thickness is very important.

However, the development of a theory to estimate the minimum thickness chip is performed in some problem. The experimental method to estimate the minimum thickness chip has been found to be quite tedious or expensive. In addition, the accuracy of the observations is strongly influenced by experimental uncertainties. Molecular dynamics simulation has been attempted, but it is only applicable for processing at the nanoscale. Some studies have also resorted to microstructural finite element simulation, but this approach involves a lot of calculation and cannot be applied to a wide range of materials.

The thermo mechanical properties of the material determine the normalized minimum chip thickness. Most properties are greatly influenced by changes in temperature, voltage and strain rate. The thermo-mechanical properties including yield strength and ductility. The variables, such as cutting of temperature, voltage and speed of deformation are in turn strongly influenced by conditions such as cutting speed and radius cutting tool. Attempts have been made to ascertain the exact manner in which the normalized minimum chip thickness depends on the cutting conditions.

3. SIZE EFFECT

Size effect phenomenon occurs due to small depth of cut. It consists in a non-linear increase in specific cutting energy when the depth of cut decreases. The specific energy of cutting is the relationship between the shear force total agent on the tool in the cutting direction and the section chip.

The effect of scale are due to the plowing of processed material due to negative rake angle, the dependence of the speed of deformation, dislocation density, the pressure on the face side due to elastic spring back and hardening the material worked in the micrometer scale.

4. LITERATURE REVIEW:

An effective methodology is needed to obtain the normalized minimum chip thickness. Liu et al. [1] has achieved this by making use of the thermo-mechanical properties of basic molecular mechanics and the theory of friction. The primary objective is to extend the knowledge of the minimum chip thickness values for other materials when they are subjected to different cutting conditions. Shear strain and strain rate with cutting temperature are important properties which were evaluated using these techniques. The cutting temperatures at both job-chip interface and tool-chip interface were considered. To facilitate the formulations, was used a model of slip-line field. This model represents the finished edge tool radius. To determine the conditions for the transition from plowing to Microcutting, the equation is used Kragelskii-Drujanov. To evaluate the effective flow stress at high strain rate, high temperature and high voltage, the model of Johnson-Cook (aluminum alloy) and the model Oxley (for carbon steel) were combined. For the experimental design, the materials used are steel 1040 and Al 6082-T6. There are two contrasting ways in which has increased the cutting speed affects minimum chip thickness. In the first place, the cutting temperature increases with increased cutting speed leading to an increase of the effect thermal softening and consequent increase in the ductility. Thus, the minimum chip thickness increases too. Secondly, with increase of speed of cutting, deformation and effectively increase the speed of deformation which increases the effect of work hardening. Therefore, the minimum chip thickness and ductility decrease. It is seen that for the machining of carbon steels, chip of minimum thickness increases with the speed of the edge of the cutting tool and increases distance. Again, the higher the carbon content of the steels, the higher the minimum chip thickness. While the processing of aluminum, it is seen that the values of minimum thickness of chips remains constant over a wide range of cutting speeds and radio edge of the tool. Thus, for the machining of carbon steels, high-speed are not used while for the aluminum alloys of machining, high speeds are used for a higher productivity.

H.S.Yoon et al. [8] proposed a model of orthogonal pattern of shear force according to the slip-line field for micro machining. Two processes of material flow processes are being considered-chip formation and plowing. The document takes into account the effects of parameters such as the effective cutting angle, depth of deformation and minimum chip thickness. The radius of the edge effect is an important effect in manufacturing processes. The tool can be reduced to a large extent, but the sharpness of the instrument cannot be reduced drastically and proportionally. So, in micro machining plowing force is an important factor instead of cutting force, which is the dominant factor in conventional machining. Another important effect is the effect of minimum chip thickness. When the undeformed chip thickness is less than the minimum thickness of the chip, chip formation occur doesn t "and there is plowing only. However, when the undeformed chip thickness exceeds a minimum value, chip formation occurs. Few experimental analysis has demonstrated that the chip formation takes place only when the undeformed chip thickness is more than 30% of the radius of the tip. This document is based on the assumption that the tool has a perfectly rounded edge. cutting performed is assumed to be orthogonal. material deforms plastically under the minimum height of the chip thickness. Another hypothesis is that the work material is not curing. Therefore, the shear stress on all cutting planes have the same values. chip is also assumed to be a free body, such that the normal force on the cutting plane is zero. paper has also focused on the effects of dead zones on metal processing micro. These areas serve as stable edges constructed on the instrument, such as the areas of stagnation in which occurs no flow of material.

Eugen axinite [2] has studied the surface roughness on micro made of titanium alloy (Ti6Al4V). Conventional turning of titanium alloys is difficult. In the first place, the tool life is short and thus form long chips that cause the problem of removal from the machine. So, micro sd of these alloys has gained in importance. When is used a tool with a tip radius, having ridges geometries corresponding to the geometry of the tool nose to be left on the finished surface. Moreover, very high normal stresses are developed in the metal on the trailing edge. This metal slides sideways relieve stress and in the process, creating a furrow increasing roughness. In particular, the soft ductile materials show problem.it is observed that in the case of surface roughness before microturning decreases with feed, reaches a minimum and then increases if the feed is further increased. The final model for the prediction of surface roughness is the roughness of the edge roughness associated with the lateral flow of plastic and kinematic "surface roughness.

Z Zhou J et al. [10] has assumed the case of ultraprecision machining to study the effect of sharpness on the tool diamond cutting surface integrity and chip of minimum thickness. Good surface integrity is an essential requirement of machining processes. Good surface integrity implies lower surface roughness and residual stresses smaller combined with high dimensional accuracy. However, the accuracy of the relative motion between the cutting edge and the workpiece governs the machining accuracy obtainable. Therefore, the operation of the machine tool must be studied. The workpiece material used is aluminum alloy. It was found that the cutting edge sharper, low surface roughness. Then, a cutting tool is preferable. To study the effect on the hardening of the layer of the machined surface, a micro Vickers was used to measure the micro hardness. It is observed that the surface machined with a cutting tool has a hardness less than a machined surface with a blunt instrument. Moreover, a tool with a large radius corresponds stress residues sharp greater for a given depth of cut. In a certain range of values of the depth of cut, it is seen that the residual stresses decrease with decreasing depth of cut. As the depth of cut reaches a critical value, the residual stress decreases while increasing the depth of cut. The effect of depth of cut on the residual stresses can be explained with the help of the size of the effect. When the depth of cut reaches values comparable to the radius of the cutting edge, there is severe rubbing or burnishing action. As a result, the specific processing increases the energy and the material near the tip of the tool are plastically deformed to a large extent. Tools give sharper cutting thickness smaller.

N. Fang et al. [4] has attempted a modeling of the formation of transformation embedded board. The size of the board can be provided and constructed quantitatively the effect of the cutting edge on the flow of chips and cutting forces can be studied in different processing conditions. The machining of the edges is constructed in a structure formed on the uneven surface and tool rake unstable during the machining of ductile materials Such alloys steels and aluminum alloys. It consists of successive layers hardened under extreme deformation tool-chip interface. This model is very important because it provides the built-up edge in the works. It also provides the chip uncurling effect that plays an important role in the processing. It establishes the relationship between the processing parameters such as the chip thickness, tool chip contact length, chip up-curl radius and cutting and thrust forces size and contour of the edge and built.

Kim et al. [9] proposed a model of orthogonal cutting model called the tip of the round diamond. This model is focused on two factors, first to the elastic recovery of the workpiece causing sliding along the free face and the other plowing. The results of this model were compared with those of "merchant model s. Hypothesis is that the cutting process is a two-dimensional plastic. Normal stress is considered constant while the variations of shear stress in the region in which the instrument is rounded. the workpiece is elastically recovered in face liquidation. E 'was observed that for the depth of cut of less than 1 micron, the cutting edge round Kim model best approximates the cutting forces compared to the model of sharp cutting edge merchant. low depth of these cut, the friction along the side opposite to the workers and negative rake angle are factors that must be considered.

Ajjarapu et al. [7] has made a study of the ductile regime machining of silicon nitride. 250nm to 10µm depth of cut are selected for testing workability. The Drucker-Prager yield criterion is implemented in software AdvantEdge to study the mechanical behavior of silicon nitride. Depth from 1 micron to 40 microns and rake angles ranging from 0 ° to -60 ° cutting are used for the numerical simulations. It was noted that negative rake angles produce greater development of higher pressures in the workpiece. Similarly, experiments have shown that the processing system is ductile when the values of depth of cut chosen are less than 1 micron.

Jiwang Yan et al. [6] attempted to discuss ductile regime turning at large tool feed. A very important problem in using ductile regime turning tool wear. The current method of using a diamond tool rounded tip introduces limitations on feed. In this paper, the authors have proposed the use of a diamond tool straight nose. A small tool results in the absence of electrical power over long distances. If the other conditions are kept constant, the volume of tool wear increases with the distance of the cut. Thus, a tool feed smaller leads to increased tool wear. A small tool feed also translates into an increase of the processing time and the low efficiency of transformation. If you use a tool diamond cutting straight, undeformed chip thickness becomes uniform along the main cutting edge. Thus, a uniform cutting mode can be expected. In the process of diamond turning, machining brittle cleavage fracture involves tensile ductile deformation during the processing involves large plastic deformation. This model adopts small corners of the board and then allows thinning of chip thickness in the range of nanometers. This model also allows for plane strain conditions. Turn ductile regime could be made in a sound feeds up to some tens of micrometers.

T.P.Leung et al. [5] have attempted to study the ductile regime diamond turning of silicon substrates. Silicon processing in the fragile regime is not suitable because of its low fracture toughness. The effect of the variation of parameters such as depth of cut, feed rate and rake angle of the tool on the ductile regime turning of silicon with a diamond tool needs to be investigated.

Three distinct regimes could be observed in the machining process, the elastic regime, the regime ductile and brittle regime. In ductile regime, the surface is smooth and it was noted that there were no cracks or pits. The regime has intensive brittle surface cracks. The orientation of the crystal is another factor that influences the critical depth of cut. The size of the cracks increases with increasing cutting depth. To obtain an optical surface of the silicon substrate in diamond turning, the chip thickness must not exceed a critical value. The surface finish has been found to be very good as the advancement or the depth of cut was put under certain values. With an increasing negative rake angle, has been found to improve the surface roughness.

Blackley et al. [3] proposed a completely different model for diamond turning brittle materials ductile regime. Two parameters, the depth of cut and the layer critical damage subsoil are used to characterize the process of removal of the material. E 'was introduced a limit process called maximum feed rate to better understand the process. It was studied the effect of the cutting angle, radius of the nose and the work environment on machinability. The material used for the experimental study is germanium and the lubricant used for machining is distilled water. Excellent workmanship is observed at negative rake angles. However, since the rake angles are becoming more negative, will decrease the quality of the surface finish. It was observed that, the processing rate for ductile germanium is better in the dry state than in the wet state using distilled water as a lubricant. With an increase of the radius of the cutting edge, the workability of the material is found to improve. Although an exact explanation of the observed phenomena has not been attempted, it can be assumed that the magnitude and direction of cutting forces play an important role in the characteristics displayed.

5. DESIGN OF EXPERIMENT

Let us we have 3 input variables, and each variable is having 3 levels. So to cover all the possible cases we have to carry out 3*3*3=27 experiments. To do these many runs it is too time consuming and tedious. So design of an experiment is done. Instead of doing all these experiments if we will follow taguchi L9 experiment then we will cover all the possible combinations.

There are two types of process variables. Controllable and uncontrollable. The uncontrollable factors are also called as noise.

Statistical process control and design of experiments, although two instruments closely related to the improvement and optimization of processes, design of experiments provides a more effective method than the statistical process control. It is a statistical method passive look at the process and then expects some information that leads to a useful change. Information passive cannot provide useful information if the process is in control. However, the design of experiments is a statistical method active: a series of tests are actually performed on the process, making changes in input, and observing the corresponding changes of the outputs. This leads to information that can lead to the improvement of processes.

Guidance for designing experiment

1. Recognition and declaration of the problem: It's very essential to fully develop all the ideas on the problem in question, and also to the specific objectives of the trial. Input from all parties concerned-engineering, marketing, customers, quality, management, and operators must be stressed. This helps to better understand the process and at the end the solution of the problem.

2. Choice of factors and levels: Choices of factors that need to be varied in the experiment should be made, the intervals on which factors are varied and specific levels at which they are made slopes. Knowledge of the process is a combination of practical knowledge and theoretical understanding and is required for the correct choice. The number of factor levels should be kept low for the screening factor. All the factors which may be of relevance must be examined. Much stress should not be laid on experience post.

3. Selection of the response variable: During the selection of the response variable, you should verify that the variable actually provides useful information about the process under study. Very often, the average or standard deviation or both are chosen as response variables.

4. Choice of experimental design: according to the sample size choice of design should be done.

5. Performing the experiment: It is necessary to carefully monitor the process to ensure whether everything is going in required manner or not. Error in this stage generally destroys the experiment.

6. Data analysis: statistical methods are applied for analyzing the results and conclusions. Graphical methods and software are also used.

7. Conclusion and Recommendation: after analyzing the data, practical conclusions were drawn from the experiment and hence a course of action was recommended.

6. Grey relational analysis:

In gray relational analysis, experimental data that is measured characteristics of quality characteristics are normalized before that varies from zero to one. This process is known as gray relational generation. Subsequently, on the basis of experimental data normalized, gray relational coefficient is calculated to represent the correlation between the desired and actual experimental data. Then the overall gray relational grade is determined by the average of the gray relational coefficient corresponding to selected answers. The overall performance characteristic of the process of multiple choice depends on the calculated gray relational able. This approach converts multiple-response-processes in an optimization problem single situation optimization response; with the objective function is gray overall relational quality. The optimal parametric combination is then evaluated that would be higher gray relational degree. The optimal factor setting to maximize the overall gray relational grade can be performed with the Taguchi method.

In gray relational analysis the normalized values can be found out by following formulae

$$x_i(k) = \frac{\max y_i(k) - y_i(k)}{max\ y_i(k) - min y_i\ (k)}$$

After this grey relational coefficient can be calculated.

$$\xi_i(k) = \frac{\Delta_{\min} + \psi\Delta_{\max}}{\Delta_{0i}(k) + \psi\Delta_{\max}}$$

The higher value of grey relational grade corresponds to intense relational degree between the reference sequence x0(k) and the given sequence *xi(k)* . The reference sequence *x0(k)* represents the best process sequence. Therefore, higher grey relational grade means that the corresponding parameter combination is closer to the optimal. The mean response for the grey relational grade with its grand mean and the main effect plot of grey relational grade are very important because optimal process condition can be evaluated from this plot.

7. Experimental setup:

The experiment was performed on the HMT NH26 lathe and the machining forces were measured with the help of a KISTLER 9272 dynamometer.

Fig(a)

Fig(b)

Fig a (attached W/P in chuck) **Fig. b** (tool, dynamometer and W/P assembly)

7.1 EXPERIMENTAL CONDITIONS (Table 1)

Workpiece material	AISI 304 STEEL
Inserts used	Uncoated cemented carbide insert (ISO P30 grade)
Insert designation	SCMT 12 04 08
Tool Geometry	−6°,−6°,6°,6°, 15°, 75°, 0.8 (mm)
Cutting velocity(m/min)	38.48,65.97,112.31
Feed(mm/rev)	0.04,0.06,0.08
Depth of cut (mm)	0.2,0.3,0.4
Environment	Dry

7.2. TOOL DESIGNATION:

SCMT 12 04 08

12 implies length of each cutting edge is 12 mm

04 implies nominal thickness of the insert is 4 mm

08 implies nose radius is 0.8 mm

7.3. WORKPIECE PROPERTIES:

AISI 304 steel

It is an austenitic standard chromium nickel steel.

Chemical composition: Table 2

ELEMENT	WEIGHT%
C	0.08
Mn	2.00
Si	1.00
Cr	18-20
Ni	8.0-10.5
P	0.045
S	0.03

7.4 MECHANICAL PROPERTIES

TABLE 3

DENSITY(x1000)Kg/m^3	8
Poisson's ratio	0.27-0.30
Elastic Modulus(Gpa)	193
Tensile Strength(Mpa)	515
Yeild strength(Mpa)	205
Elongation(%)	40
Hardness(HRB)	88

8. EXPERIMENTAL DATA:

Table no-4

TABLE 2-ORTHOGONAL ARRAY L9(3^3) OF THE EXPERIMENT RUNS AND RESULTS

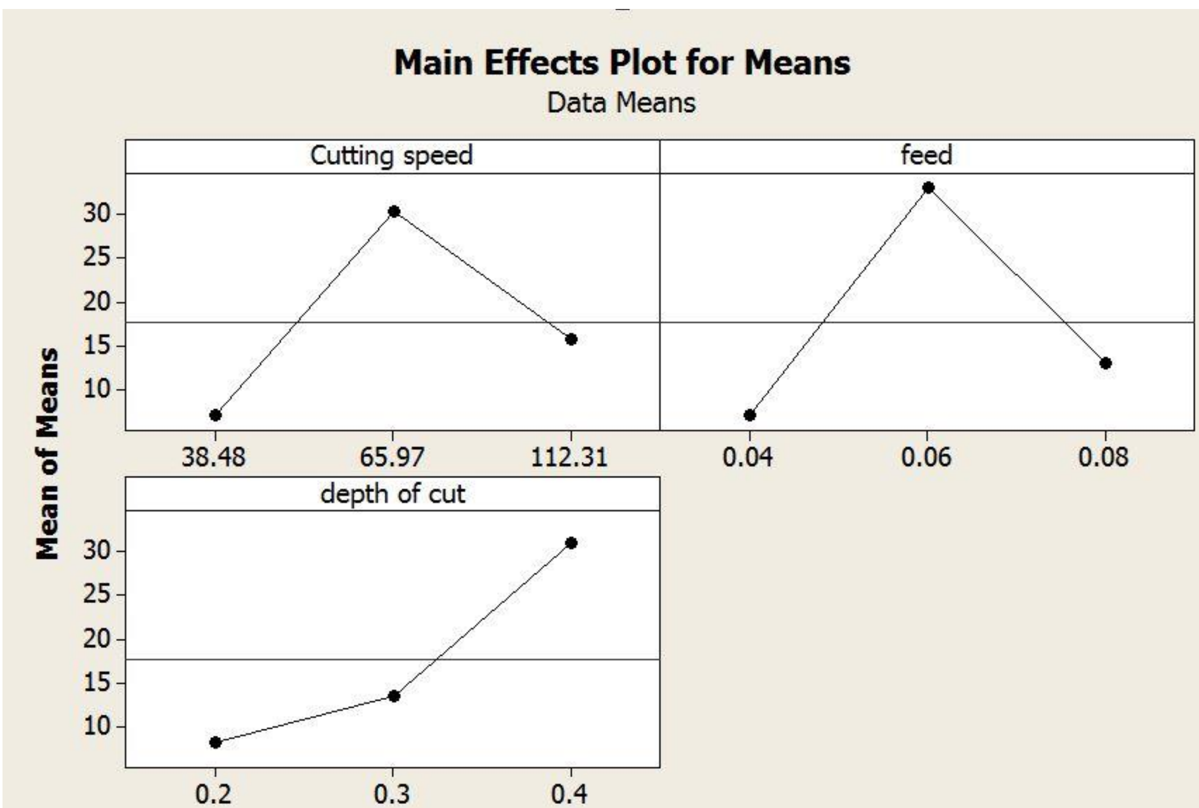
RUN NO.	Cutting speed	feed	depth of cut	Fx	Fy	Fz	SR	TOOL WEAR	CHIP THICKNESS
1	38.48	0.04	0.2	9	4	4	3.6	0.071	0.08
2	38.48	0.06	0.3	6	1	4	0.8	0.137	0.11
3	38.48	0.08	0.4	6	4	6	2.5	0.057	0.14
4	65.97	0.04	0.3	6	1	4	0.44	0.113	0.808
5	65.97	0.06	0.4	81	88	45	3.2	0.143	0.1
6	65.97	0.08	0.2	4	6	6	2.6	0.078	0.11
7	112.31	0.04	0.4	6	1	6	0.8	0.094	0.08
8	112.31	0.06	0.2	12	4	4	1.2	0.11	0.11
9	112.31	0.08	0.3	29	12	14	1.4	0.112	0.13

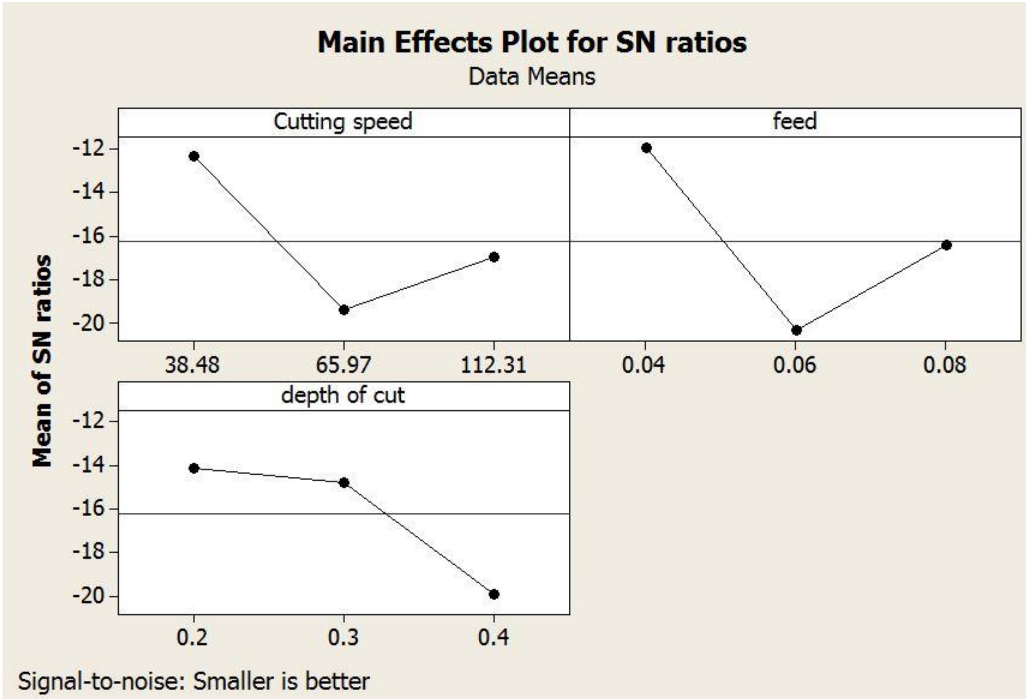
Analysis using Taguchi Method

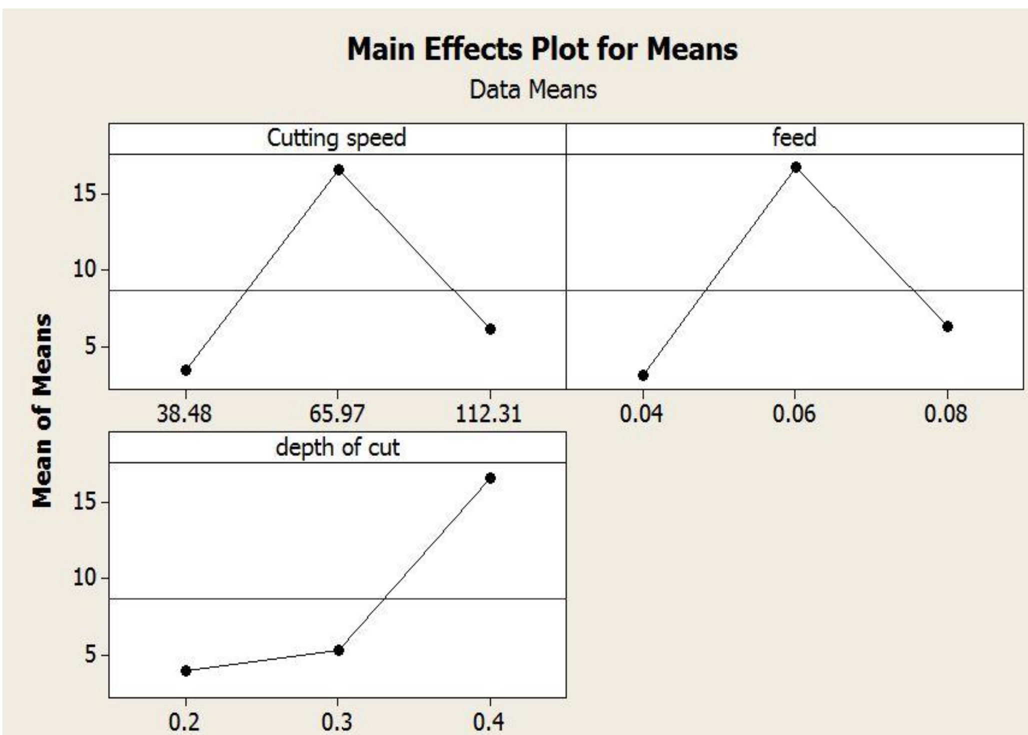
TABLE NO-5

Cutting speed	feed	depth of cut	Fx	Fy	Fz	SR	TOOL WEAR	CHIP THICKNESS	SNRA1	STDE1	MEAN1
38.48	0.04	0.2	9	4	4	3.6	0.071	0.08	-14.0128	3.1823	4.1342
38.48	0.06	0.3	6	1	4	0.8	0.137	0.11	-10.3067	2.508	2.3874
38.48	0.08	0.4	6	4	6	2.5	0.057	0.14	-12.7533	2.519	3.7114
65.97	0.04	0.3	6	1	4	0.44	0.113	0.808	-10.2699	2.5745	2.3106
65.97	0.06	0.4	81	88	45	3.2	0.143	0.1	-35.1429	41.511	43.4686
65.97	0.08	0.2	4	6	6	2.6	0.078	0.11	-12.7768	2.4996	3.7356
112.31	0.04	0.4	6	1	6	0.8	0.094	0.08	-11.682	2.9597	2.7788
112.31	0.06	0.2	12	4	4	1.2	0.11	0.11	-15.5011	4.6537	4.262
112.31	0.08	0.3	29	12	14	1.4	0.112	0.13	-23.74	11.6646	11.3024

Different curves has been plotted




Main Effects Plot for SN ratios
Data Means
Cutting speed
feed
depth of cut
Mean of SN ratios
-12
-14
-16
-18
-20
38.48
65.97
112.31
0.04
0.06
0.08
0.2
0.3
0.4
Signal-to-noise: Smaller is better


Main Effects Plot for Means
Data Means
Cutting speed
feed
depth of cut
Mean of Means
15
10
5
38.48
65.97
112.31
0.04
0.06
0.08
0.2
0.3
0.4

Grey relational analysis:

Normalized value table TABLE NO-6

NORMALISED VALUE TABLE									
RUN NO.	Cutting speed	feed	depth of cut	Fx	Fy	Fz	SR	TOOL WEAR	CHIP THICKNESS
1	38.48	0.04	0.2	0.935	0.966	0.953	0	0.837	1
2	38.48	0.06	0.3	0.974	1	0.953	0.886	0.67	0.959
3	38.48	0.08	0.4	0.974	0.966	0.907	0.348	1	0.918
4	65.97	0.04	0.3	0.974	1	0.953	1	0.349	0
5	65.97	0.06	0.4	0	0	0	0.127	0	0.973
6	65.97	0.08	0.2	1	0.943	0.907	0.316	0.756	0.959
7	112.31	0.04	0.4	0.974	1	0.907	0.886	0.57	1
8	112.31	0.06	0.2	0.896	0.966	0.953	0.759	0.384	0.959
9	112.31	0.08	0.3	0.675	0.874	0.721	0.696	0.36	0.931

Deviation value=1-normalised value

TABLE NO-7

DEVIATION TABLE					
Fx	Fy	Fz	SR	TOOL WEAR	CHIP THICKNESS
0.065	0.034	0.047	1	0.163	0
0.026	0	0.047	0.114	0.33	0.041
0.026	0.034	0.093	0.652	0	0.082
0.026	0	0.047	0	0.651	1
1	1	1	0.873	1	0.027
0	0.057	0.093	0.684	0.244	0.041
0.026	0	0.093	0.114	0.43	0
0.104	0.034	0.047	0.241	0.616	0.041
0.325	0.126	0.279	0.304	0.64	0.069

TABLE NO-8

Table for grey relational coefficient:

GRAY RELATIONAL CO-EFFICIENT					
Fx	Fy	Fz	SR	TOOL WEAR	CHIP THICKNESS
0.885	0.9363	1.000	0.333	0.754147813	1
0.951	1	1.000	0.814	0.602409639	0.924
0.951	0.9363	0.922	0.434	1	0.859
0.951	1	1.000	1	0.434404865	0.333
0.333	0.3333	0.365	0.364	0.333333333	0.949
1	0.8977	0.922	0.422	0.672043011	0.924
0.951	1	0.922	0.814	0.537634409	1.000
0.828	0.9363	1.000	0.675	0.448028674	0.924
0.606	0.7987	0.702	0.622	0.438596491	0.879

Calculation of gray relational grade:

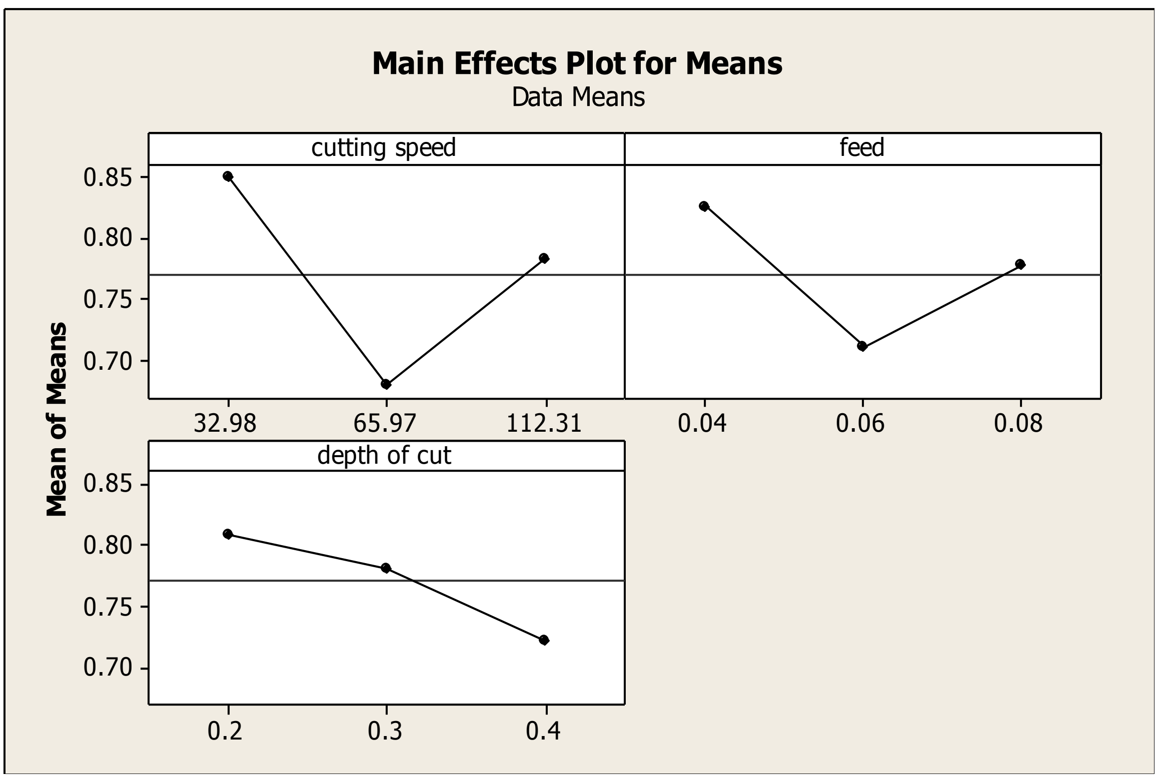
TABLE NO-9

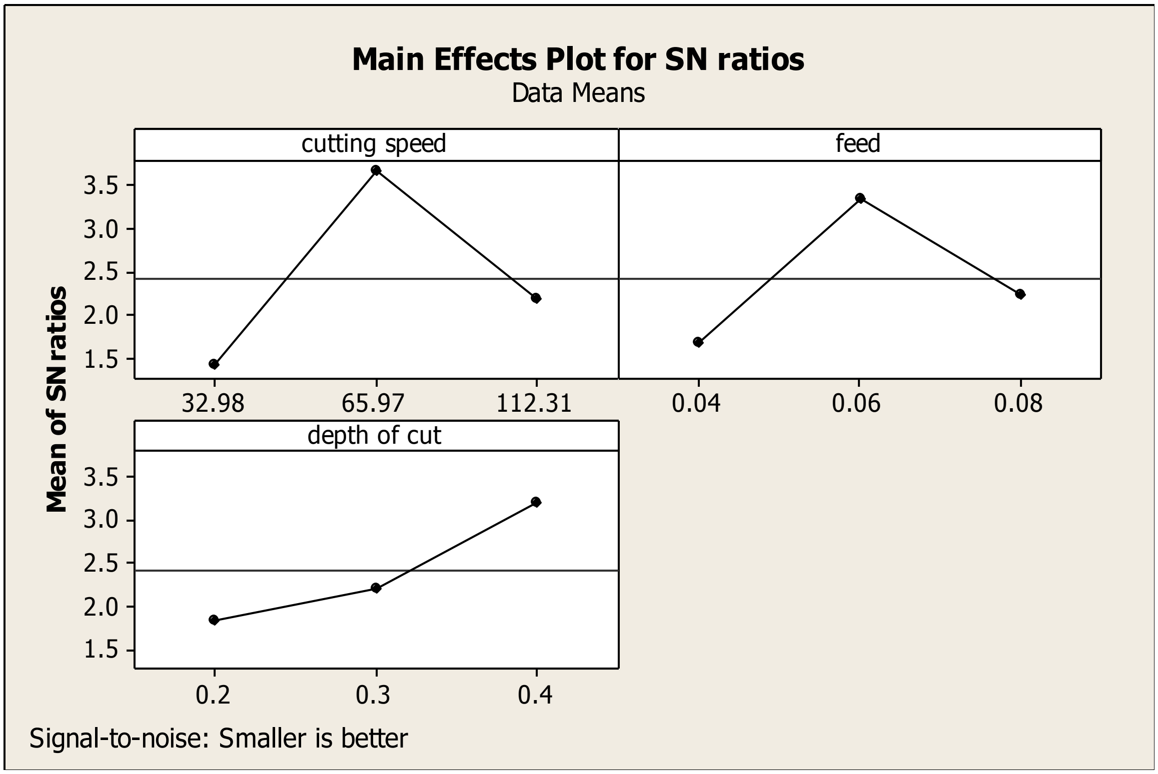
GRAY RELATIONAL CO-EFFICIENT						GRAY RELATIONAL GRADE
Fx	Fy	Fz	SR	TOOL WEAR	CHIP THICKNESS	
0.885	0.936	1.000	0.333	0.754	1.000	0.818
0.951	1.000	1.000	0.814	0.602	0.924	0.882
0.951	0.936	0.922	0.434	1.000	0.859	0.850
0.951	1.000	1.000	1.000	0.434	0.333	0.786
0.333	0.333	0.365	0.364	0.333	0.949	0.446
1.000	0.898	0.922	0.422	0.672	0.924	0.806
0.951	1.000	0.922	0.814	0.538	1.000	0.871
0.828	0.936	1.000	0.675	0.448	0.924	0.802
0.606	0.799	0.702	0.622	0.439	0.879	0.674

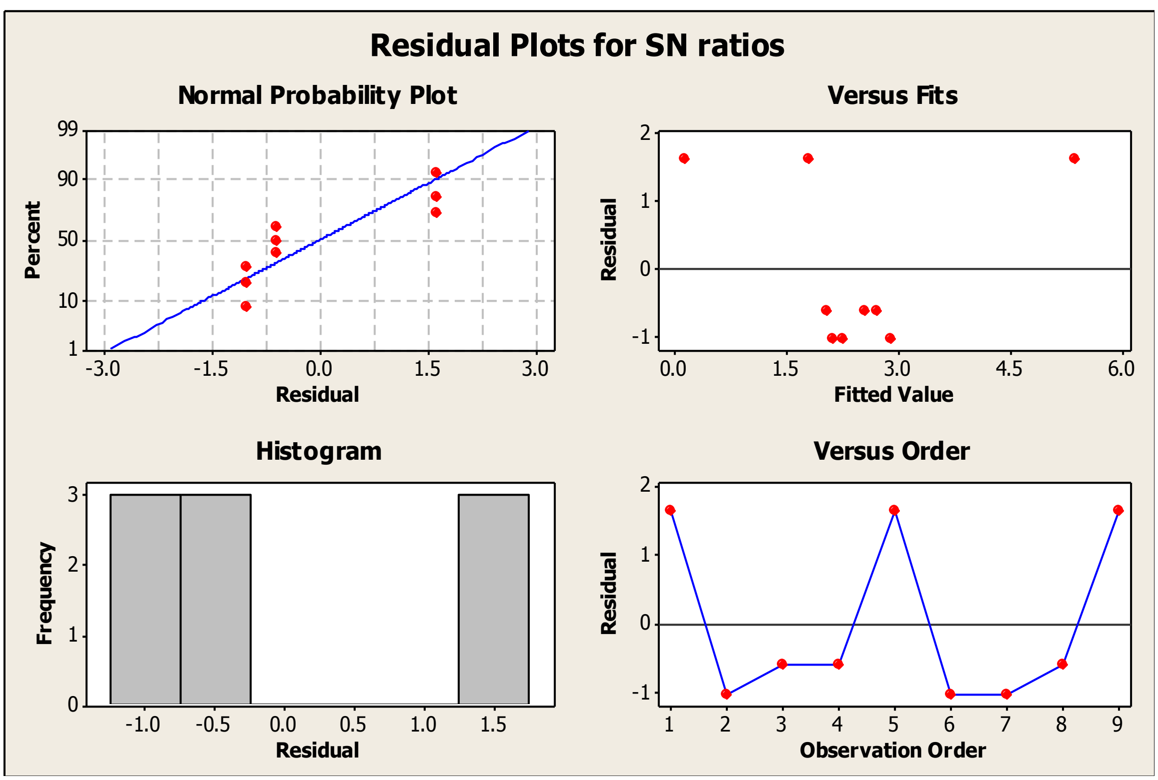
GRAY TAGUCHI ANALYSIS:

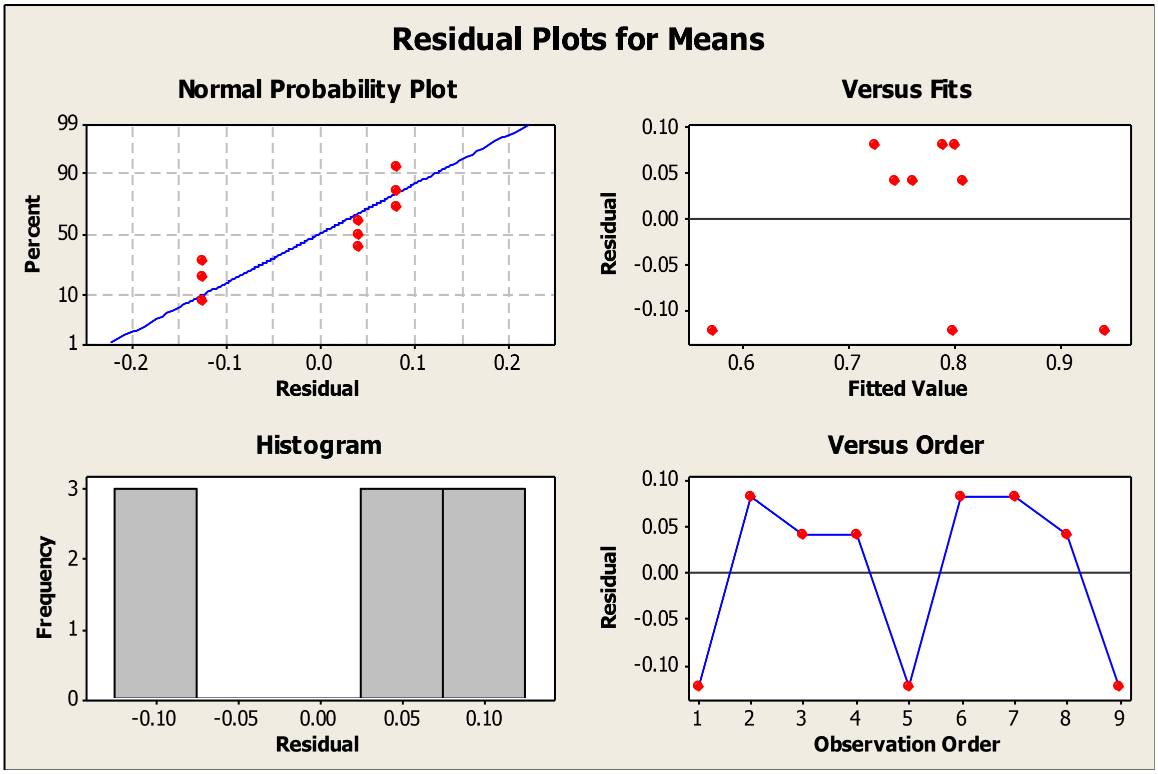
cutting sp	feed	depth of c	grey index	SNRA1	MEAN1	FITS_MEA	FITS_SN1	RESI_MEA	RESI_SN1	SRES_MEA	SRES_SN1
32.98	0.04	0.2	0.818	1.743578	0.818128	0.942608	0.102075	-0.12448	1.641502	-1.39028	1.399233
32.98	0.06	0.3	0.882	1.091405	0.881921	0.799591	2.120734	0.08233	-1.02933	0.919511	-0.87741
32.98	0.08	0.4	0.850	1.407428	0.85041	0.808259	2.019602	0.042151	-0.61217	0.470768	-0.52182
65.97	0.04	0.3	0.786	2.087298	0.786385	0.744234	2.699471	0.042151	-0.61217	0.470768	-0.52182
65.97	0.06	0.4	0.446	7.008113	0.446267	0.570747	5.366611	-0.12448	1.641502	-1.39028	1.399233
65.97	0.08	0.2	0.806	1.868542	0.806442	0.724112	2.897871	0.08233	-1.02933	0.919511	-0.87741
112.31	0.04	0.4	0.871	1.201357	0.870828	0.788498	2.230686	0.08233	-1.02933	0.919511	-0.87741
112.31	0.06	0.2	0.802	1.918045	0.801859	0.759708	2.530218	0.042151	-0.61217	0.470768	-0.52182
112.31	0.08	0.3	0.674	3.422107	0.674364	0.798845	1.780605	-0.12448	1.641502	-1.39028	1.399233

DIFFERENT PLOT:




Main Effects Plot for SN ratios
Data Means
cutting speed
feed
depth of cut
Mean of SN ratios
3.5
3.0
2.5
2.0
1.5
32.98
65.97
112.31
0.04
0.06
0.08
0.2
0.3
0.4
Signal-to-noise: Smaller is better


Residual Plots for SN ratios
Normal Probability Plot
Percent
Residual
Versus Fits
Residual
Fitted Value
Histogram
Frequency
Residual
Versus Order
Residual
Observation Order



ANOVA TABLE FOR S/N RATIO

Source	DF	Seq ss	Adj ss	Adj ms	F	P
Cutting speed	2	7.780	7.780	3.890	0.63	0.614
Feed	2	4.294	4.294	2.147	0.35	0.734
Doc	2	2.994	2.994	1.497	0.24	0.805
Residual error	2	12.368	12.386	6.193		
Total	8	27.448				

RESPONSE TABLE FOR S/N RATIO

LEVEL	CUTTING SPEED	FEED	DEPTH OF CUT
1	1.414	1.667	1.843
2	3.655	3.339	2.200
3	2.181	2.233	3.206
DELTA	2.241	1.662	1.362
RANK	1	2	3

RESPONSE TABLE FOR MEANS

LEVEL	CUTTING SPEED	FEED	DEPTH OF CUT
1	0.8502	0.8251	0.8088
2	0.6797	0.7100	0.7809
3	0.7824	0.7771	0.7225
DELTA	0.1705	0.1151	0.0863
RANK	1	2	3

ANOVA TABLE FOR MEANS

SOURCE	DF	SEQ SS	ADJ SS	ADJ MS	F	P
CUTTING SPEED	2	0.04419	0.04419	0.22095	0.61	0.620
FEED	2	0.02005	0.02005	0.010025	0.28	0.783
DEPTH OF CUT	2	0.01164	0.01164	0.005819	0.16	0.861
RESIDUAL ERROR	2	0.07215	0.07215	0.036075		
TOTAL	8	0.14803				

RESULTS AND DISCUSSION:

The following results concluded from this experiment such that our main objective to optimize the modeling of process parameters of TURNING in stainless steel material. Such as

1. Here the optimal conditions of three process parameters are of feed rate 0.06, of cutting speed 32.98, depth of cut 0.3.
2. From the graph of larger-the-best of S/N ratio the minimum value occurred at **1.09** for feed rate in 2nd level, cutting speed in 1ST level and doc in 2^{nd} level.
3. From the graph of residual versus fitted value the points are not form any standard platform. Hence it shows no error.
4. From the normal probability plot of residuals 5 points are closely placed at the slop of standardized residual versus percent.
5. In the normal probability plot of the residuals for mean and S/N ratio, All the points lie close to the line, Hence the experiment is correct.
6. In the ANOVA table for means the P-value has maximum value i.e. 0.831 in doc parameter. Hence doc is more significant than other factors.
7. The histogram plot represents normally distributed graph. Hence our experimental analysis is correct.

Conclusion

Experiments are planned and conducted on lathe machine with solid carbide insert and stainless steel taken as work-piece material to optimize the turning operation. The purposed Grey based relational Taguchi method is beneficial for optimization of multi-responded control parameters in turning process. The main objective of this study was to determine the optimum settings of feed rate, cutting speed and depth of cut so that the forces, tool wear, chip thickness, and surface roughness can be minimized.

The optimum values are found out to be cutting speed 32.98m/min, feed 0.06 mm/rev and depth of cut 0.3mm/rev.

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